

FIG. 1. MEMBRANE DESICCATION HEAT PUMP
GENERAL CONCEPT

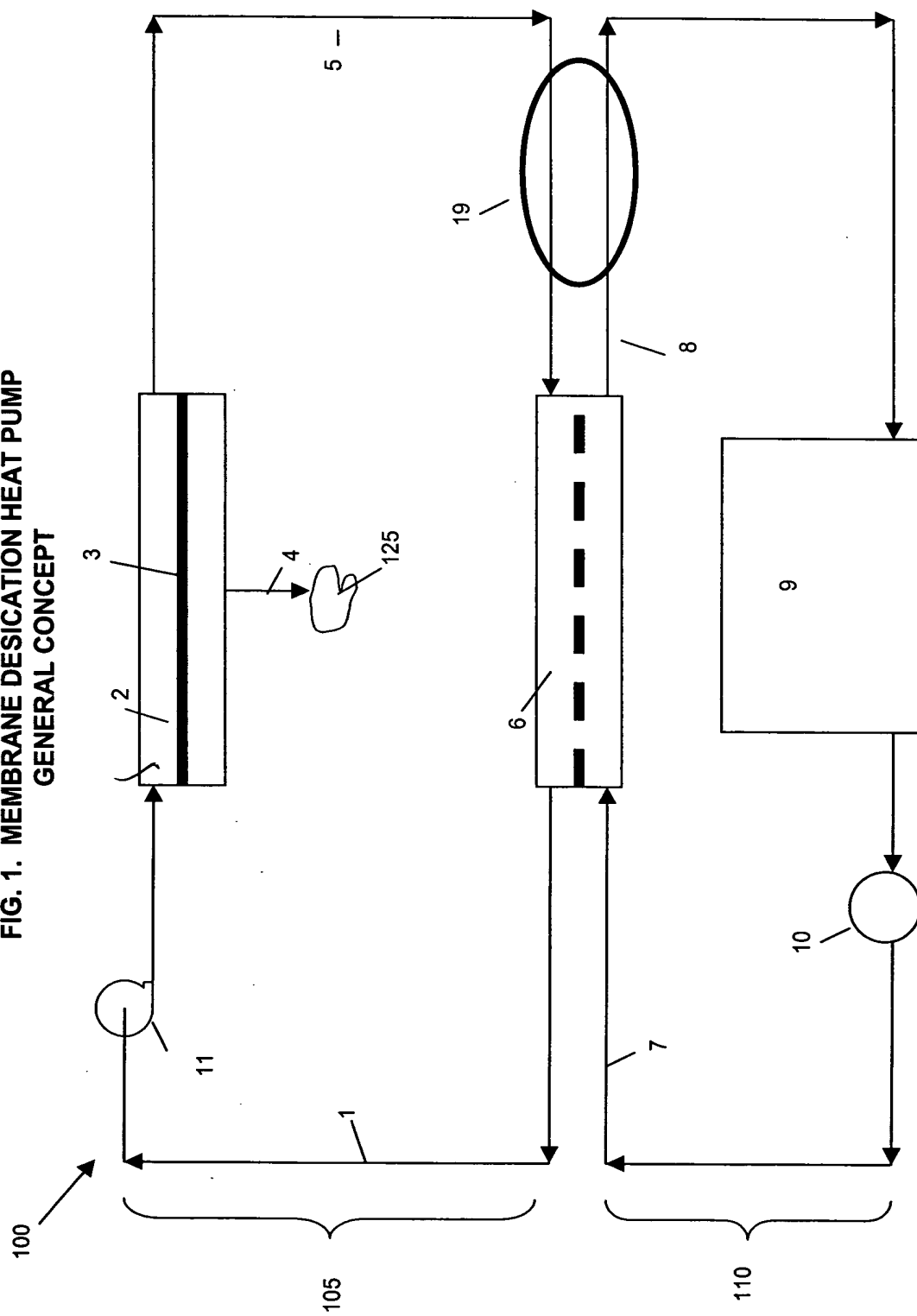


FIG. 2A. MIXED PERMEATE FLOW

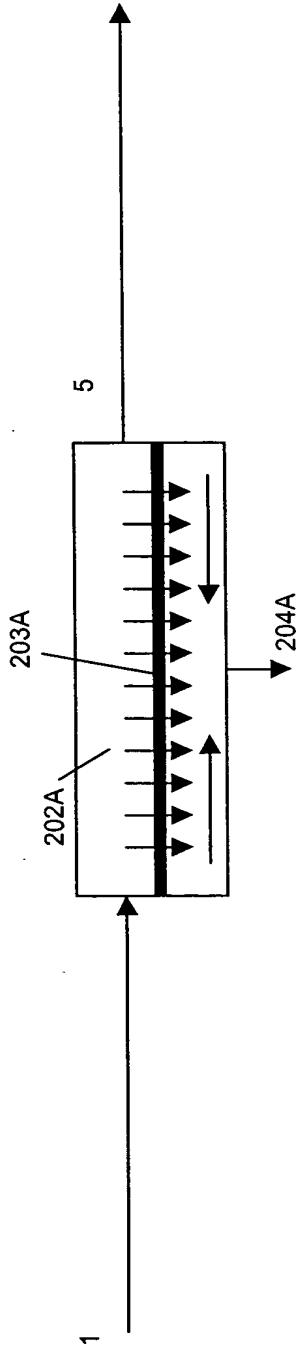


FIG. 2B. COCURRENT PERMEATE FLOW

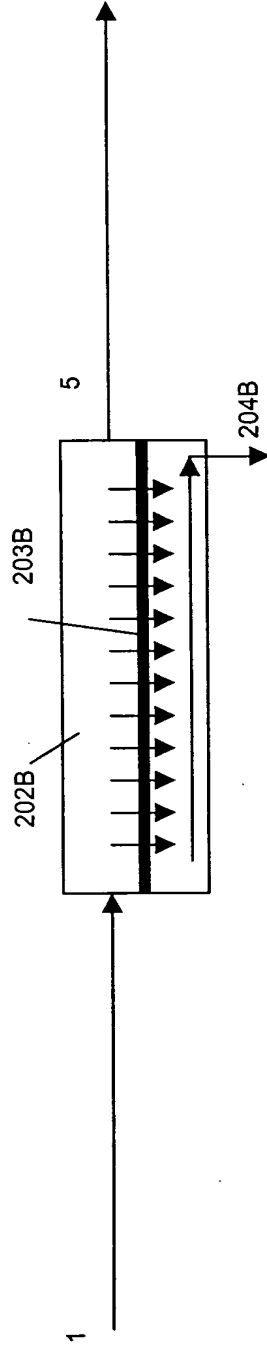
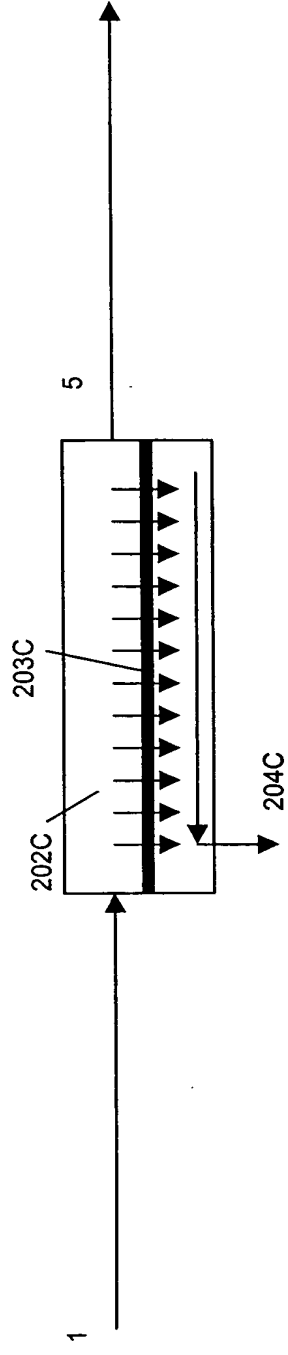


FIG. 2C. COUNTERCURRENT PERMEATE FLOW



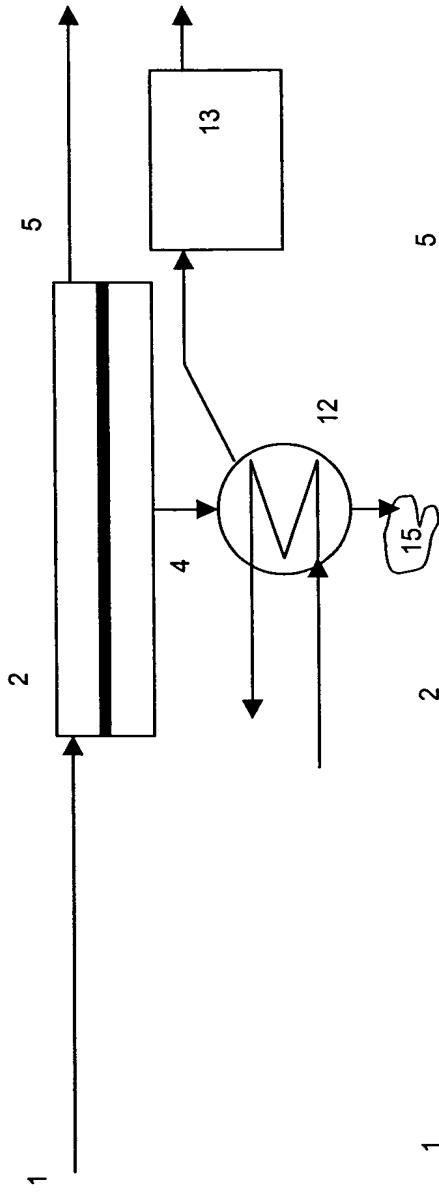


FIG. 3A
VACUUM

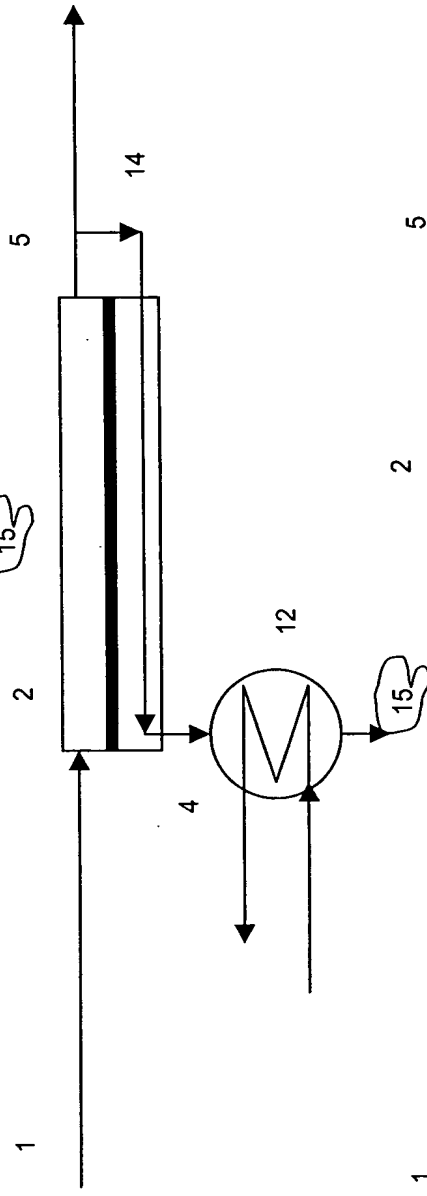


FIG. 3B
REFLUX

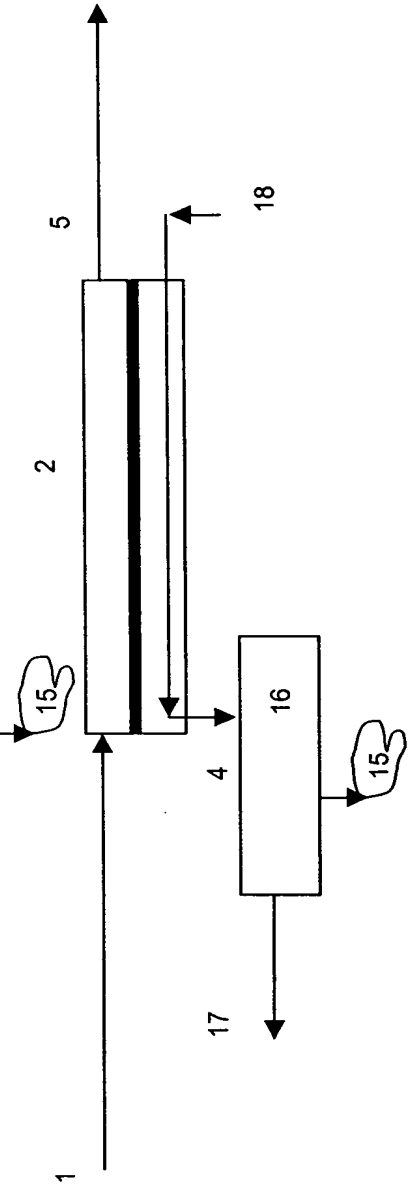


FIG. 3C
SWEEPING

FIG. 4. HEAT PUMP - OPEN CYCLES

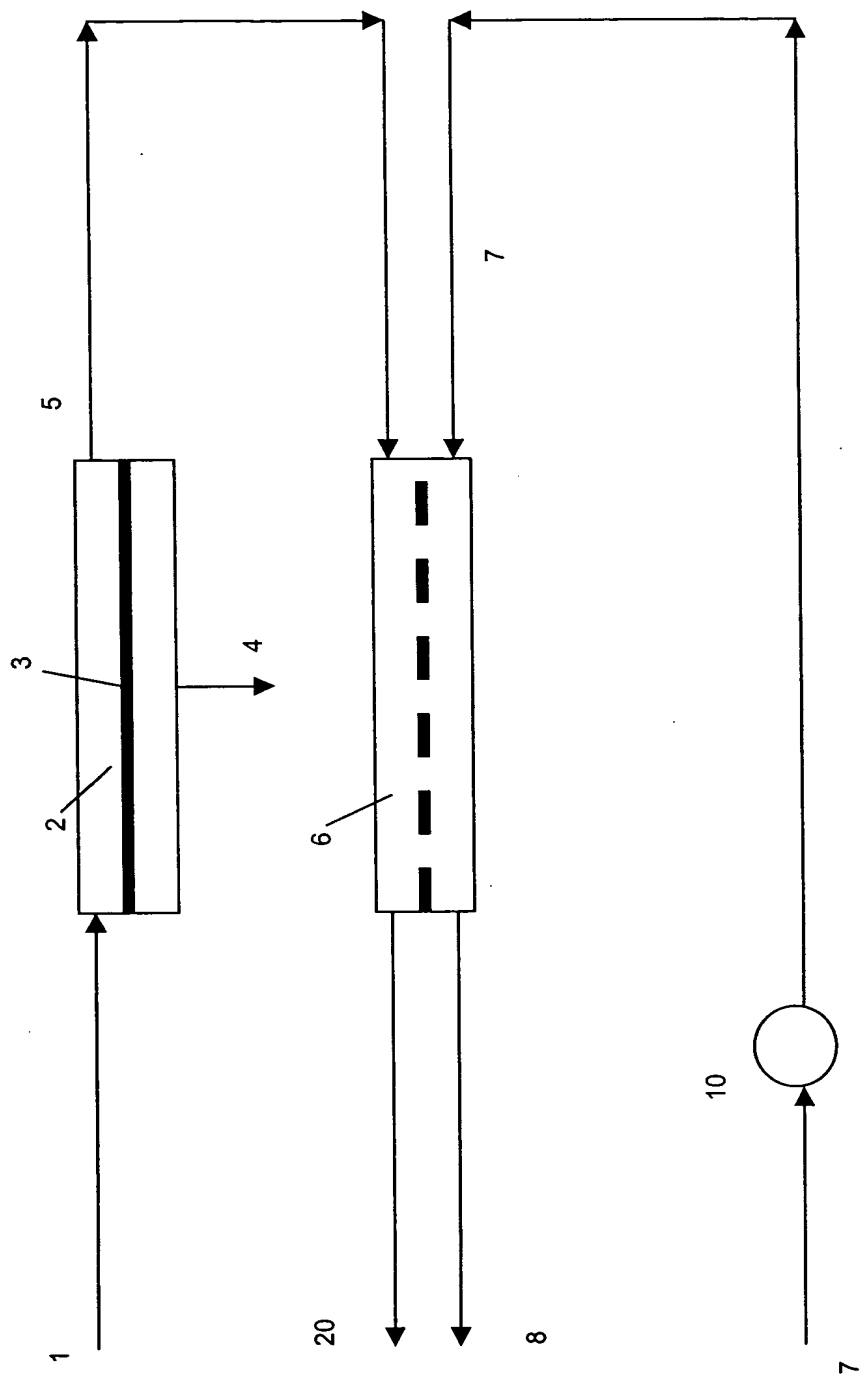


FIG. 5. OPEN CYCLE GAS CHILLING / AIR CONDITIONING

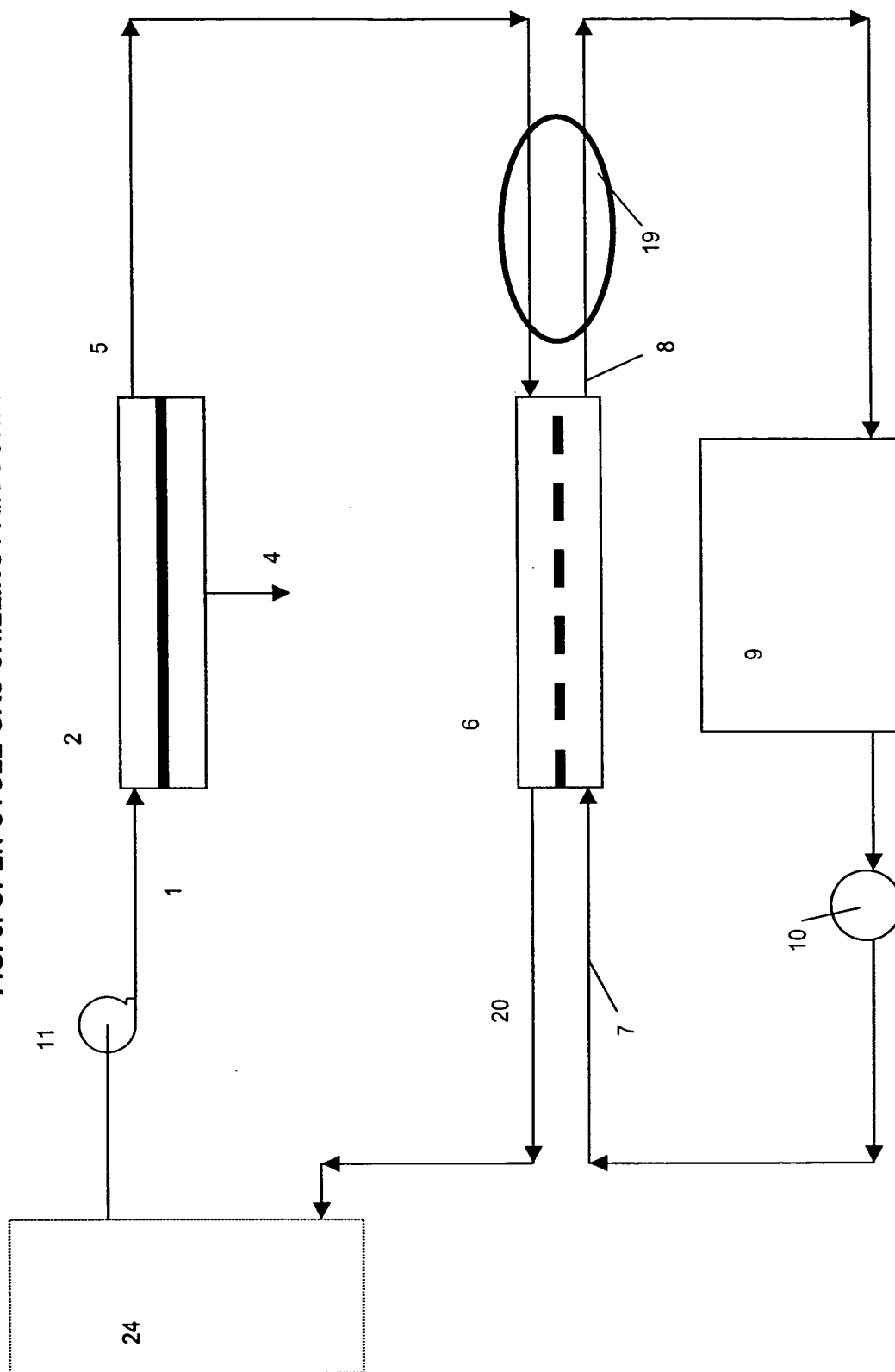


FIG. 6. LIQUID CHILLING - OPEN CYCLE

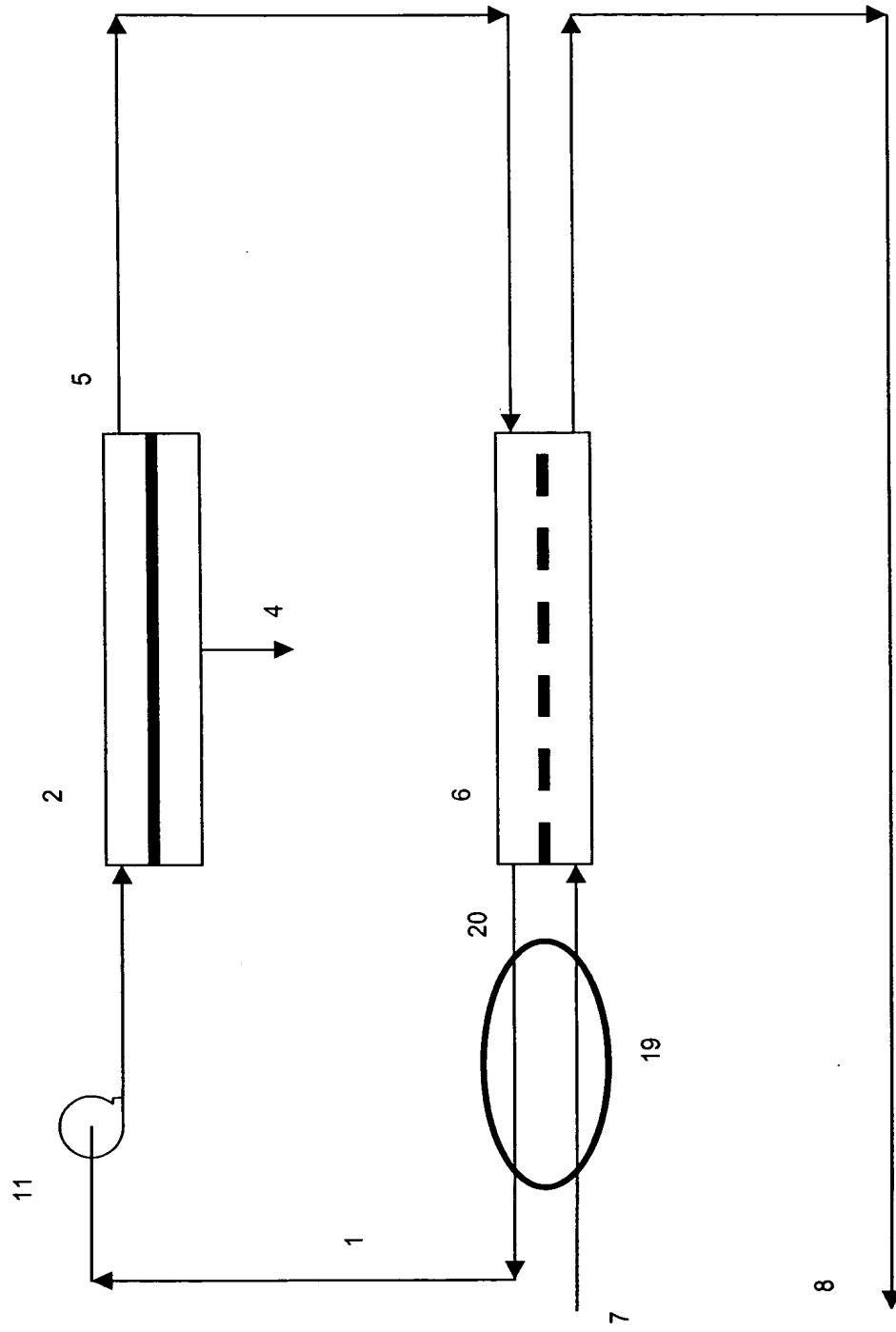


FIG. 7. GAS CHILLING - CLOSED CYCLE

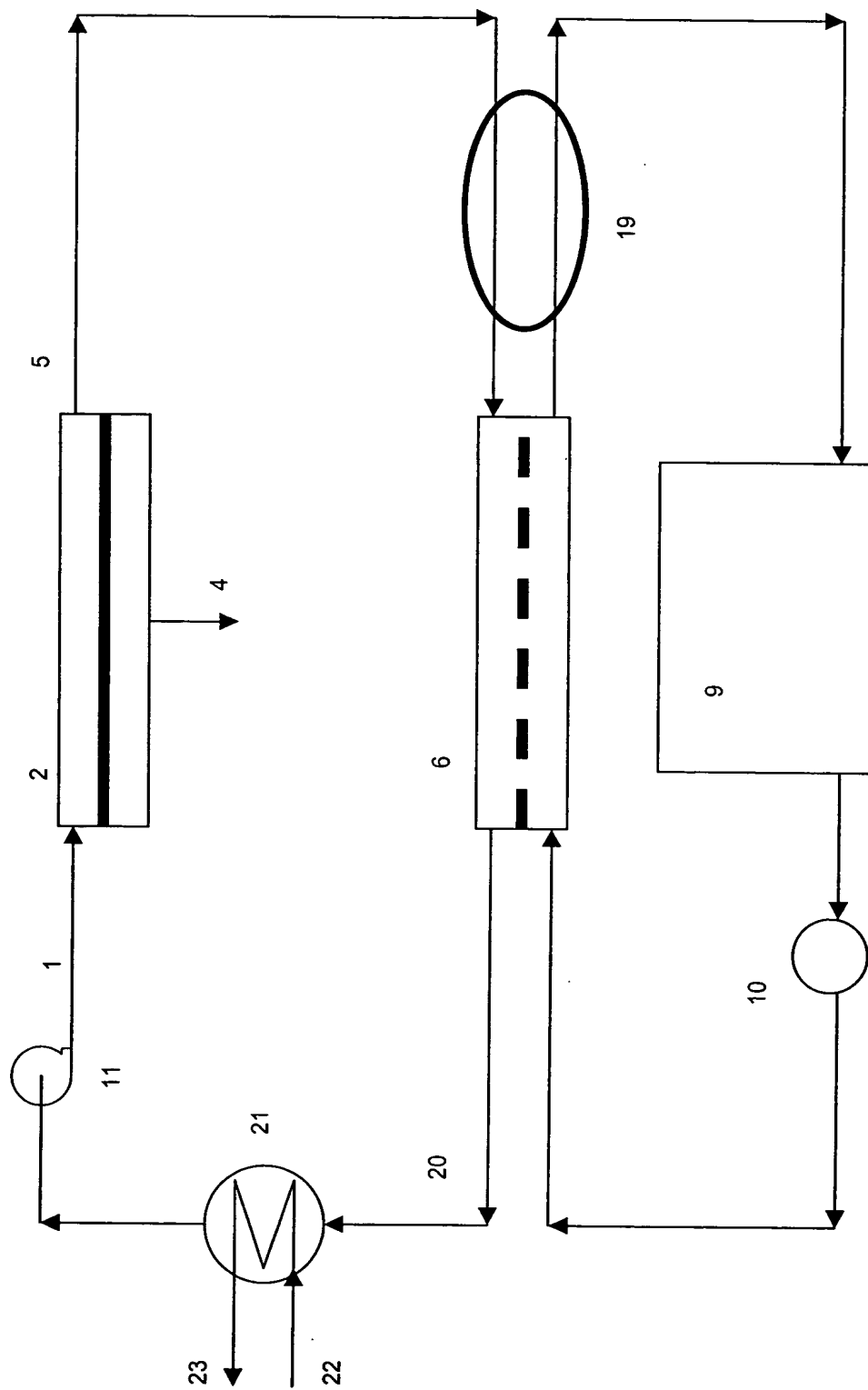


FIG. 8. CLOSED CYCLE LIQUID CHILLING

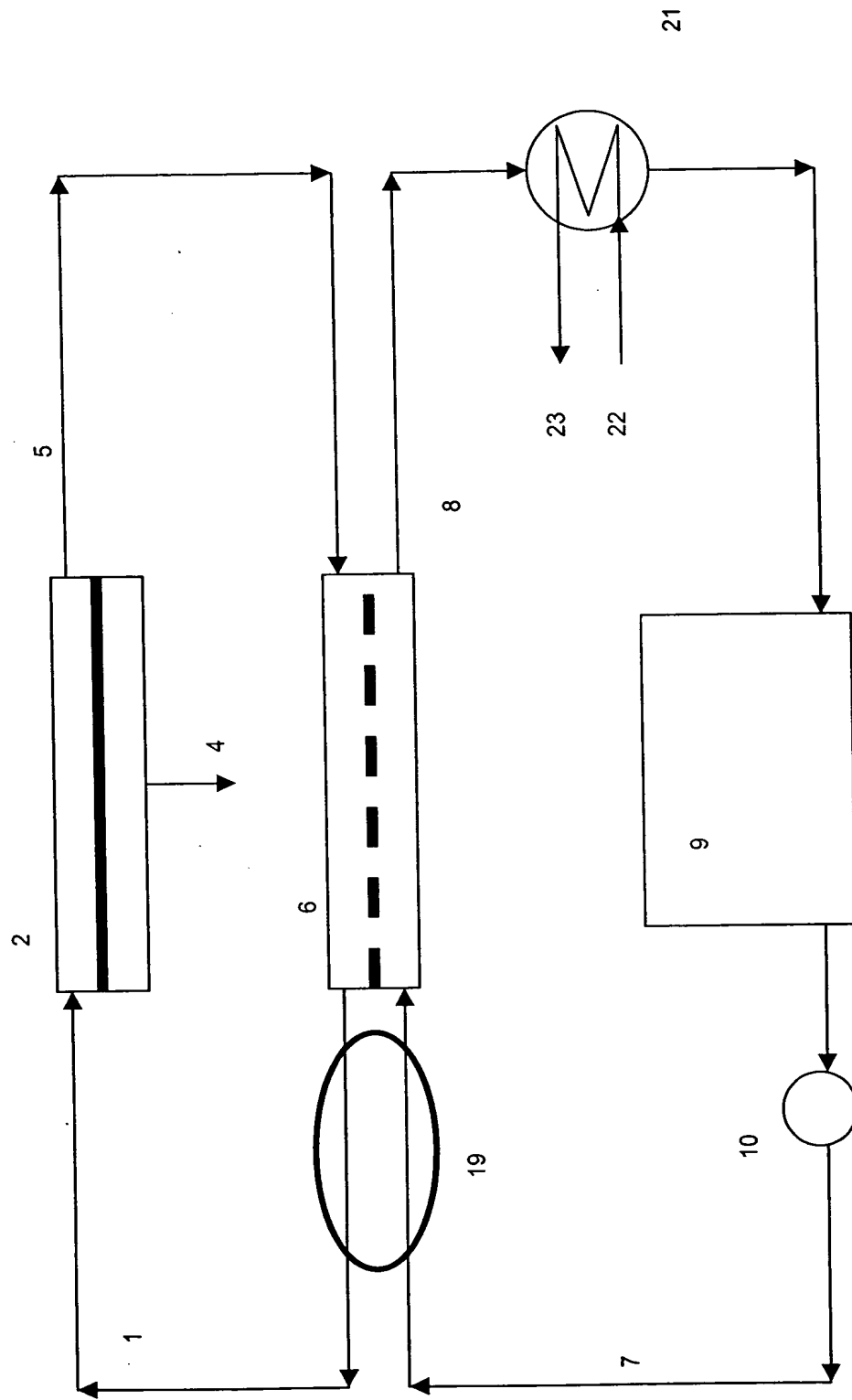
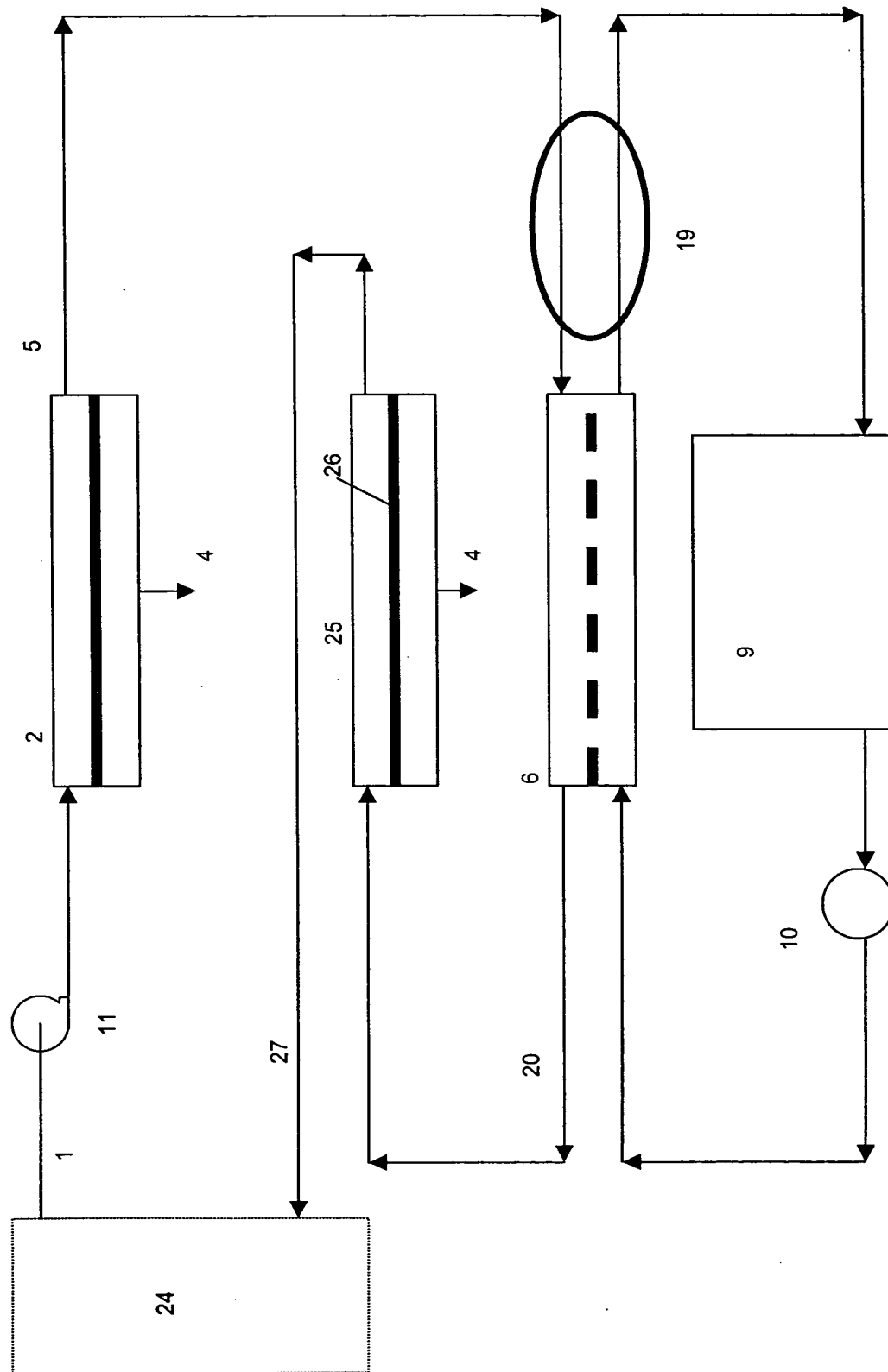


FIG. 9. GAS CHILLING/AIR CONDITIONING + VAPOR CONTENT CONTROL



The diagram illustrates a two-stage refrigeration cycle. The process begins with a saturated vapor (1) entering a vertical compressor (2). The high-pressure superheated vapor (3) then enters a horizontal condenser (4), which is cooled by cooling water. The liquid (5) flows into a flash separator (6). The flash separator separates the liquid (7) from the flash gas (8). The liquid (7) enters a second vertical compressor (9). The high-pressure superheated vapor (10) enters a second horizontal condenser (11), also cooled by cooling water. The liquid (12) flows into a second flash separator (13). The flash separator separates the liquid (14) from the flash gas (15). The liquid (14) enters a third vertical compressor (16). The high-pressure superheated vapor (17) enters a third horizontal condenser (18), cooled by cooling water. The liquid (19) flows into a fourth flash separator (20). The flash separator separates the liquid (21) from the flash gas (22). The liquid (21) enters a fourth vertical compressor (23). The high-pressure superheated vapor (24) enters a fourth horizontal condenser (25), cooled by cooling water. The liquid (26) flows into a fifth flash separator (27). The flash separator separates the liquid (28) from the flash gas (29). The liquid (28) enters a fifth vertical compressor (30). The high-pressure superheated vapor (31) enters a fifth horizontal condenser (32), cooled by cooling water. The liquid (33) flows into a sixth flash separator (34). The flash separator separates the liquid (35) from the flash gas (36). The liquid (35) enters a sixth vertical compressor (37). The high-pressure superheated vapor (38) enters a sixth horizontal condenser (39), cooled by cooling water. The liquid (40) flows into a seventh flash separator (41). The flash separator separates the liquid (42) from the flash gas (43). The liquid (42) enters a seventh vertical compressor (44). The high-pressure superheated vapor (45) enters a seventh horizontal condenser (46), cooled by cooling water. The liquid (47) flows into an eighth flash separator (48). The flash separator separates the liquid (49) from the flash gas (50). The liquid (49) enters an eighth vertical compressor (51). The high-pressure superheated vapor (52) enters an eighth horizontal condenser (53), cooled by cooling water. The liquid (54) flows into a ninth flash separator (55). The flash separator separates the liquid (56) from the flash gas (57). The liquid (56) enters a ninth vertical compressor (58). The high-pressure superheated vapor (59) enters a ninth horizontal condenser (60), cooled by cooling water. The liquid (61) flows into a tenth flash separator (62). The flash separator separates the liquid (63) from the flash gas (64). The liquid (63) enters a tenth vertical compressor (65). The high-pressure superheated vapor (66) enters a tenth horizontal condenser (67), cooled by cooling water. The liquid (68) flows into an eleventh flash separator (69). The flash separator separates the liquid (70) from the flash gas (71). The liquid (70) enters an eleventh vertical compressor (72). The high-pressure superheated vapor (73) enters an eleventh horizontal condenser (74), cooled by cooling water. The liquid (75) flows into a twelfth flash separator (76). The flash separator separates the liquid (77) from the flash gas (78). The liquid (77) enters a twelfth vertical compressor (79). The high-pressure superheated vapor (80) enters a twelfth horizontal condenser (81), cooled by cooling water. The liquid (82) flows into a thirteenth flash separator (83). The flash separator separates the liquid (84) from the flash gas (85). The liquid (84) enters a thirteenth vertical compressor (86). The high-pressure superheated vapor (87) enters a thirteenth horizontal condenser (88), cooled by cooling water. The liquid (89) flows into a fourteenth flash separator (89). The flash separator separates the liquid (90) from the flash gas (91). The liquid (90) enters a fourteenth vertical compressor (92). The high-pressure superheated vapor (93) enters a fourteenth horizontal condenser (94), cooled by cooling water. The liquid (95) flows into a fifteenth flash separator (95). The flash separator separates the liquid (96) from the flash gas (97). The liquid (96) enters a fifteenth vertical compressor (98). The high-pressure superheated vapor (99) enters a fifteenth horizontal condenser (100), cooled by cooling water. The liquid (101) flows into a sixteenth flash separator (101). The flash separator separates the liquid (102) from the flash gas (103). The liquid (102) enters a sixteenth vertical compressor (104). The high-pressure superheated vapor (105) enters a sixteenth horizontal condenser (106), cooled by cooling water. The liquid (107) flows into a seventeenth flash separator (107). The flash separator separates the liquid (108) from the flash gas (109). The liquid (108) enters a seventeenth vertical compressor (110). The high-pressure superheated vapor (111) enters a seventeenth horizontal condenser (112), cooled by cooling water. The liquid (113) flows into an eighteenth flash separator (113). The flash separator separates the liquid (114) from the flash gas (115). The liquid (114) enters an eighteenth vertical compressor (116). The high-pressure superheated vapor (117) enters an eighteenth horizontal condenser (118), cooled by cooling water. The liquid (119) flows into a nineteenth flash separator (119). The flash separator separates the liquid (120) from the flash gas (121). The liquid (120) enters a nineteenth vertical compressor (122). The high-pressure superheated vapor (123) enters a nineteenth horizontal condenser (124), cooled by cooling water. The liquid (125) flows into a twentieth flash separator (125). The flash separator separates the liquid (126) from the flash gas (127). The liquid (126) enters a twentieth vertical compressor (128). The high-pressure superheated vapor (129) enters a twentieth horizontal condenser (130), cooled by cooling water. The liquid (131) flows into a twenty-first flash separator (131). The flash separator separates the liquid (132) from the flash gas (133). The liquid (132) enters a twenty-first vertical compressor (134). The high-pressure superheated vapor (135) enters a twenty-first horizontal condenser (136), cooled by cooling water. The liquid (137) flows into a twenty-second flash separator (137). The flash separator separates the liquid (138) from the flash gas (139). The liquid (138) enters a twenty-second vertical compressor (140). The high-pressure superheated vapor (141) enters a twenty-second horizontal condenser (142), cooled by cooling water. The liquid (143) flows into a twenty-third flash separator (143). The flash separator separates the liquid (144) from the flash gas (145). The liquid (144) enters a twenty-third vertical compressor (146). The high-pressure superheated vapor (147) enters a twenty-third horizontal condenser (148), cooled by cooling water. The liquid (149) flows into a twenty-fourth flash separator (149). The flash separator separates the liquid (150) from the flash gas (151). The liquid (150) enters a twenty-fourth vertical compressor (152). The high-pressure superheated vapor (153) enters a twenty-fourth horizontal condenser (154), cooled by cooling water. The liquid (155) flows into a twenty-fifth flash separator (155). The flash separator separates the liquid (156) from the flash gas (157). The liquid (156) enters a twenty-fifth vertical compressor (158). The high-pressure superheated vapor (159) enters a twenty-fifth horizontal condenser (160), cooled by cooling water. The liquid (161) flows into a twenty-sixth flash separator (161). The flash separator separates the liquid (162) from the flash gas (163). The liquid (162) enters a twenty-sixth vertical compressor (164). The high-pressure superheated vapor (165) enters a twenty-sixth horizontal condenser (166), cooled by cooling water. The liquid (167) flows into a twenty-seventh flash separator (167). The flash separator separates the liquid (168) from the flash gas (169). The liquid (168) enters a twenty-seventh vertical compressor (170). The high-pressure superheated vapor (171) enters a twenty-seventh horizontal condenser (172), cooled by cooling water. The liquid (173) flows into a twenty-eighth flash separator (173). The flash separator separates the liquid (174) from the flash gas (175). The liquid (174) enters a twenty-eighth vertical compressor (176). The high-pressure superheated vapor (177) enters a twenty-eighth horizontal condenser (178), cooled by cooling water. The liquid (179) flows into a twenty-ninth flash separator (179). The flash separator separates the liquid (180) from the flash gas (181). The liquid (180) enters a twenty-ninth vertical compressor (182). The high-pressure superheated vapor (183) enters a twenty-ninth horizontal condenser (184), cooled by cooling water. The liquid (185) flows into a thirtieth flash separator (185). The flash separator separates the liquid (186) from the flash gas (187). The liquid (186) enters a thirtieth vertical compressor (188). The high-pressure superheated vapor (189) enters a thirtieth horizontal condenser (190), cooled by cooling water. The liquid (191) flows into a thirty-first flash separator (191). The flash separator separates the liquid (192) from the flash gas (193). The liquid (192) enters a thirty-first vertical compressor (194). The high-pressure superheated vapor (195) enters a thirty-first horizontal condenser (196), cooled by cooling water. The liquid (197) flows into a thirty-second flash separator (197). The flash separator separates the liquid (198) from the flash gas (199). The liquid (198) enters a thirty-second vertical compressor (200). The high-pressure superheated vapor (201) enters a thirty-second horizontal condenser (202), cooled by cooling water. The liquid (203) flows into a thirty-third flash separator (203). The flash separator separates the liquid (204) from the flash gas (205). The liquid (204) enters a thirty-third vertical compressor (206). The high-pressure superheated vapor (207) enters a thirty-third horizontal condenser (208), cooled by cooling water. The liquid (209) flows into a thirty-fourth flash separator (209). The flash separator separates the liquid (210) from the flash gas (211). The liquid (210) enters a thirty-fourth vertical compressor (212). The high-pressure superheated vapor (213) enters a thirty-fourth horizontal condenser (214), cooled by cooling water. The liquid (215) flows into a thirty-fifth flash separator (215). The flash separator separates the liquid (216) from the flash gas (217). The liquid (216) enters a thirty-fifth vertical compressor (218). The high-pressure superheated vapor (219) enters a thirty-fifth horizontal condenser (220), cooled by cooling water. The liquid (221) flows into a thirty-sixth flash separator (221). The flash separator separates the liquid (222) from the flash gas (223). The liquid (222) enters a thirty-sixth vertical compressor (224). The high-pressure superheated vapor (225) enters a thirty-sixth horizontal condenser (226), cooled by cooling water. The liquid (227) flows into a thirty-seventh flash separator (227). The flash separator separates the liquid (228) from the flash gas (229). The liquid (228) enters a thirty-seventh vertical compressor (230). The high-pressure superheated vapor (231) enters a thirty-seventh horizontal condenser (232), cooled by cooling water. The liquid (233) flows into a thirty-eighth flash separator (233). The flash separator separates the liquid (234) from the flash gas (235). The liquid (234) enters a thirty-eighth vertical compressor (236). The high-pressure superheated vapor (237) enters a thirty-eighth horizontal condenser (238), cooled by cooling water. The liquid (239) flows into a thirty-ninth flash separator (239). The flash separator separates the liquid (240) from the flash gas (241). The liquid (240) enters a thirty-ninth vertical compressor (242). The high-pressure superheated vapor (243) enters a thirty-ninth horizontal condenser (244), cooled by cooling water. The liquid (245) flows into a fortieth flash separator (245). The flash separator separates the liquid (246) from the flash gas (247). The liquid (246) enters a fortieth vertical compressor (248). The high-pressure superheated vapor (249) enters a fortieth horizontal condenser (250), cooled by cooling water. The liquid (251) flows into a forty-first flash separator (251). The flash separator separates the liquid (252) from the flash gas (253). The liquid (252) enters a forty-first vertical compressor (254). The high-pressure superheated vapor (255) enters a forty-first horizontal condenser (256), cooled by cooling water. The liquid (257) flows into a forty-second flash separator (257). The flash separator separates the liquid (258) from the flash gas (259). The liquid (258) enters a forty-second vertical compressor (260). The high-pressure superheated vapor (261) enters a forty-second horizontal condenser (262), cooled by cooling water. The liquid (263) flows into a forty-third flash separator (263). The flash separator separates the liquid (264) from the flash gas (265). The liquid (264) enters a forty-third vertical compressor (266). The high-pressure superheated vapor (267) enters a forty-third horizontal condenser (268), cooled by cooling water. The liquid (269) flows into a forty-fourth flash separator (269). The flash separator separates the liquid (270) from the flash gas (271). The liquid (270) enters a forty-fourth vertical compressor (272). The high-pressure superheated vapor (273) enters a forty-fourth horizontal condenser (274), cooled by cooling water. The liquid (275) flows into a forty-fifth flash separator (275). The flash separator separates the liquid (276) from the flash gas (277). The liquid (276) enters a forty-fifth vertical compressor (278). The high-pressure superheated vapor (279) enters a forty-fifth horizontal condenser (280), cooled by cooling water. The liquid (281) flows into a forty-sixth flash separator (281). The flash separator separates the liquid (282) from the flash gas (283). The liquid (282) enters a forty-sixth vertical compressor (284). The high-pressure superheated vapor (285) enters a forty-sixth horizontal condenser (286), cooled by cooling water. The liquid (287) flows into a forty-seventh flash separator (287). The flash separator separates the liquid (288) from the flash gas (289). The liquid (288) enters a forty-seventh vertical compressor (290). The high-pressure superheated vapor (291) enters a forty-seventh horizontal condenser (292), cooled by cooling water. The liquid (293) flows into a forty-eighth flash separator (293). The flash separator separates the liquid (294) from the flash gas (295). The liquid (294) enters a forty-eighth vertical compressor (296). The high-pressure superheated vapor (297) enters a forty-eighth horizontal condenser (298), cooled by cooling water. The liquid (299) flows into a forty-ninth flash separator (299). The flash separator separates the liquid (300) from the flash gas (301). The liquid (300) enters a forty-ninth vertical compressor (302). The high-pressure superheated vapor (303) enters a

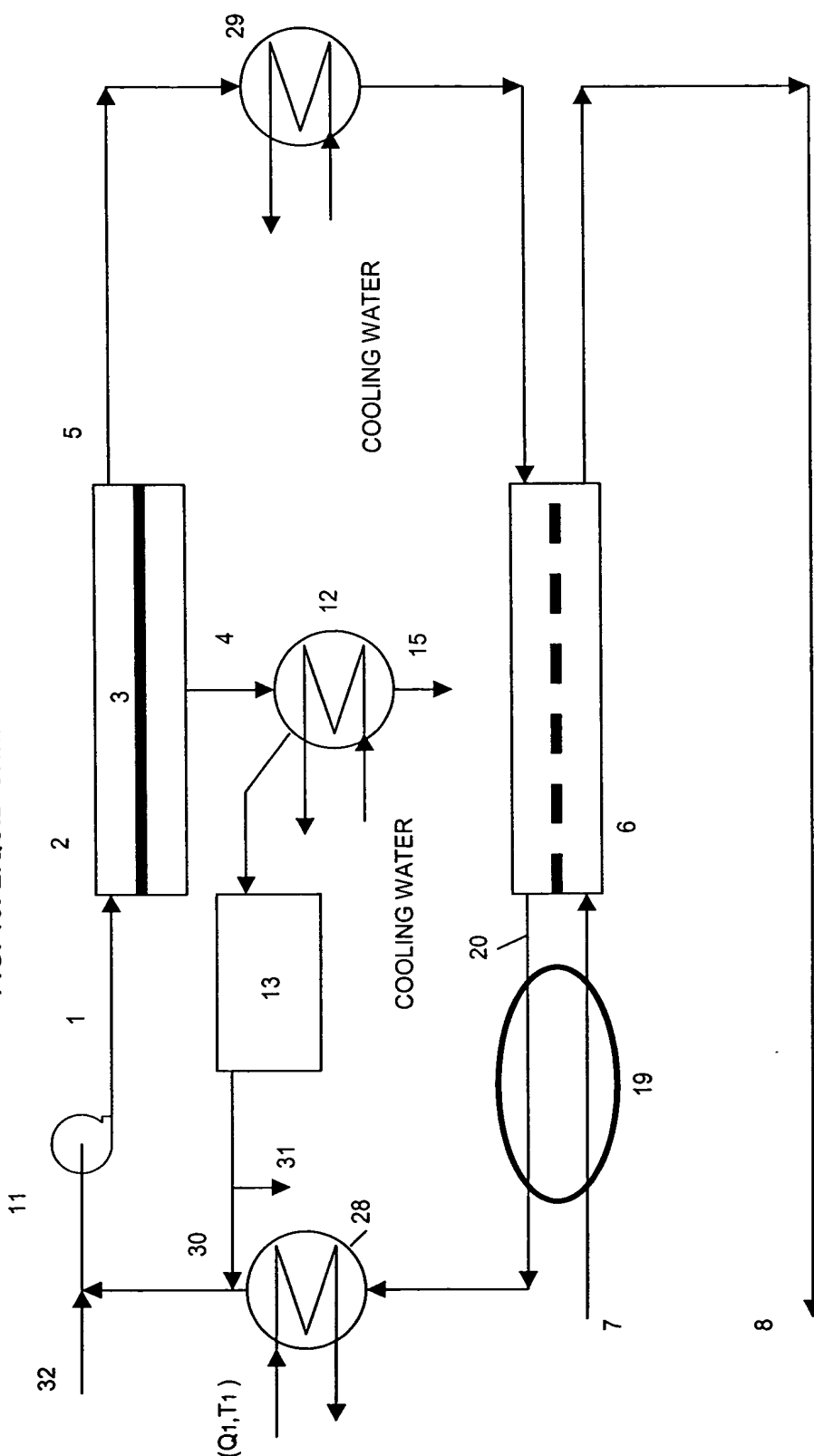


FIG. 11. LIQUID CHILLING - OPEN CYCLE + REFLUX

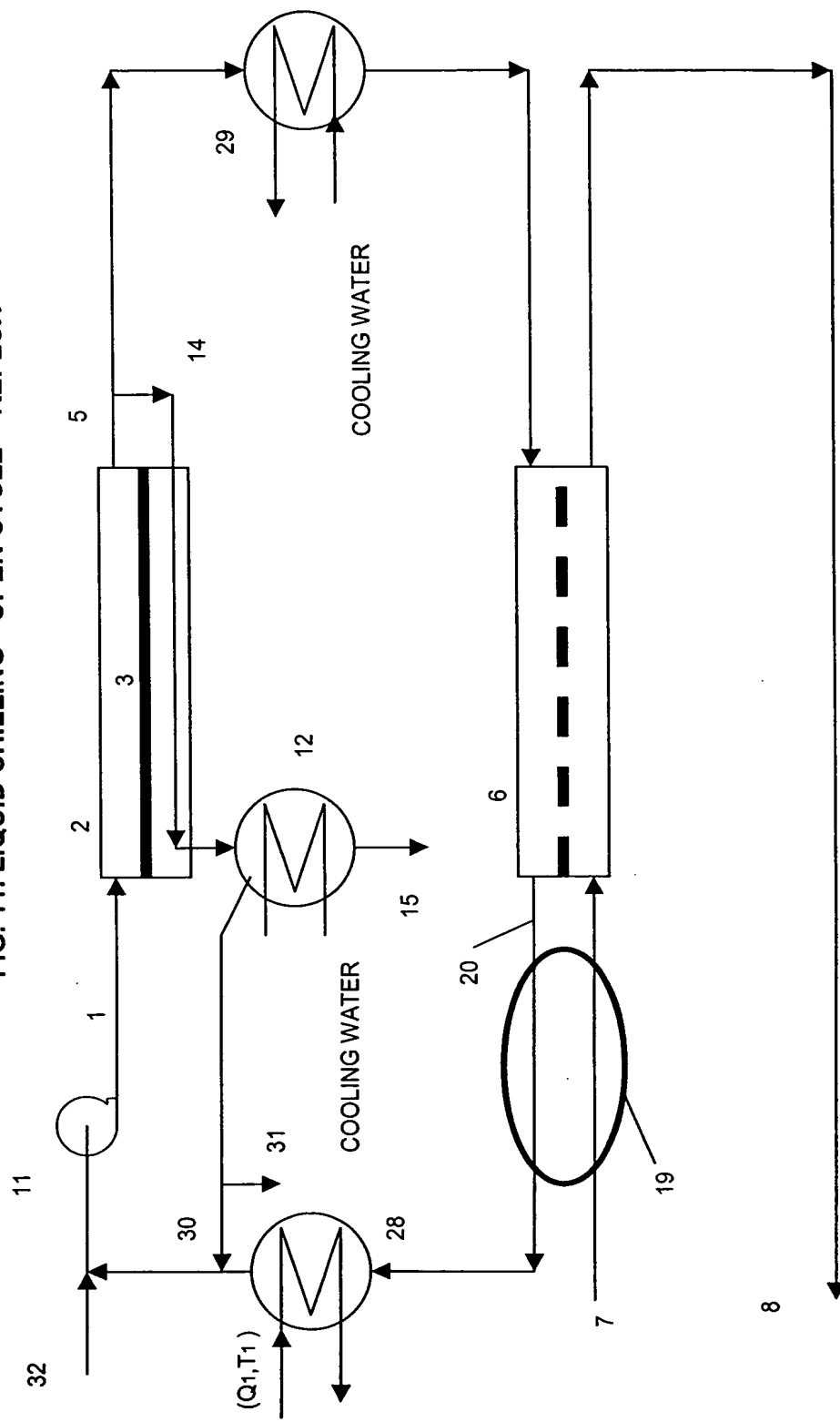


FIG. 12. AIR CONDITIONING - DETAILED

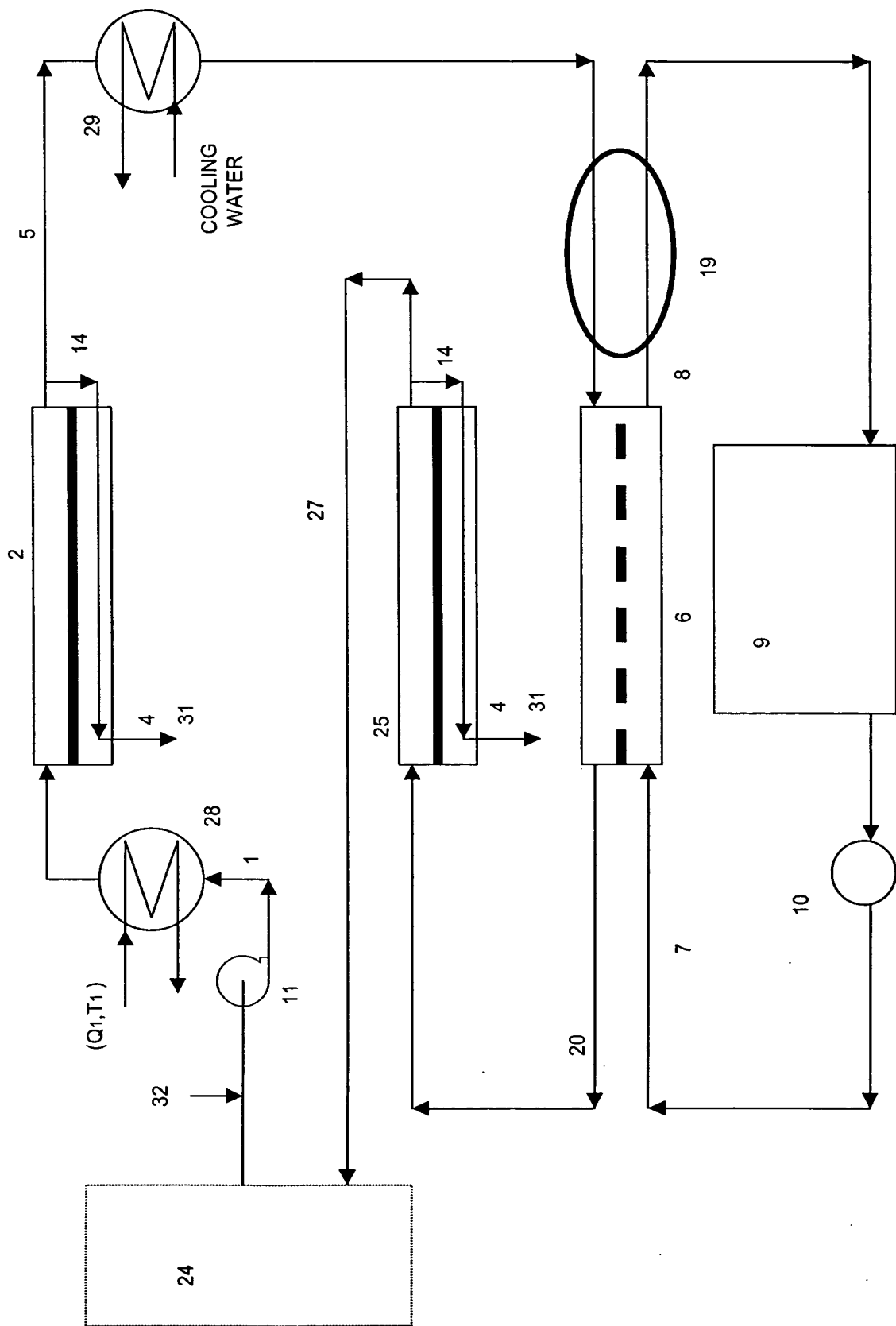


FIG. 13. MEMBRANE HEAT PUMP
HEATING MODE

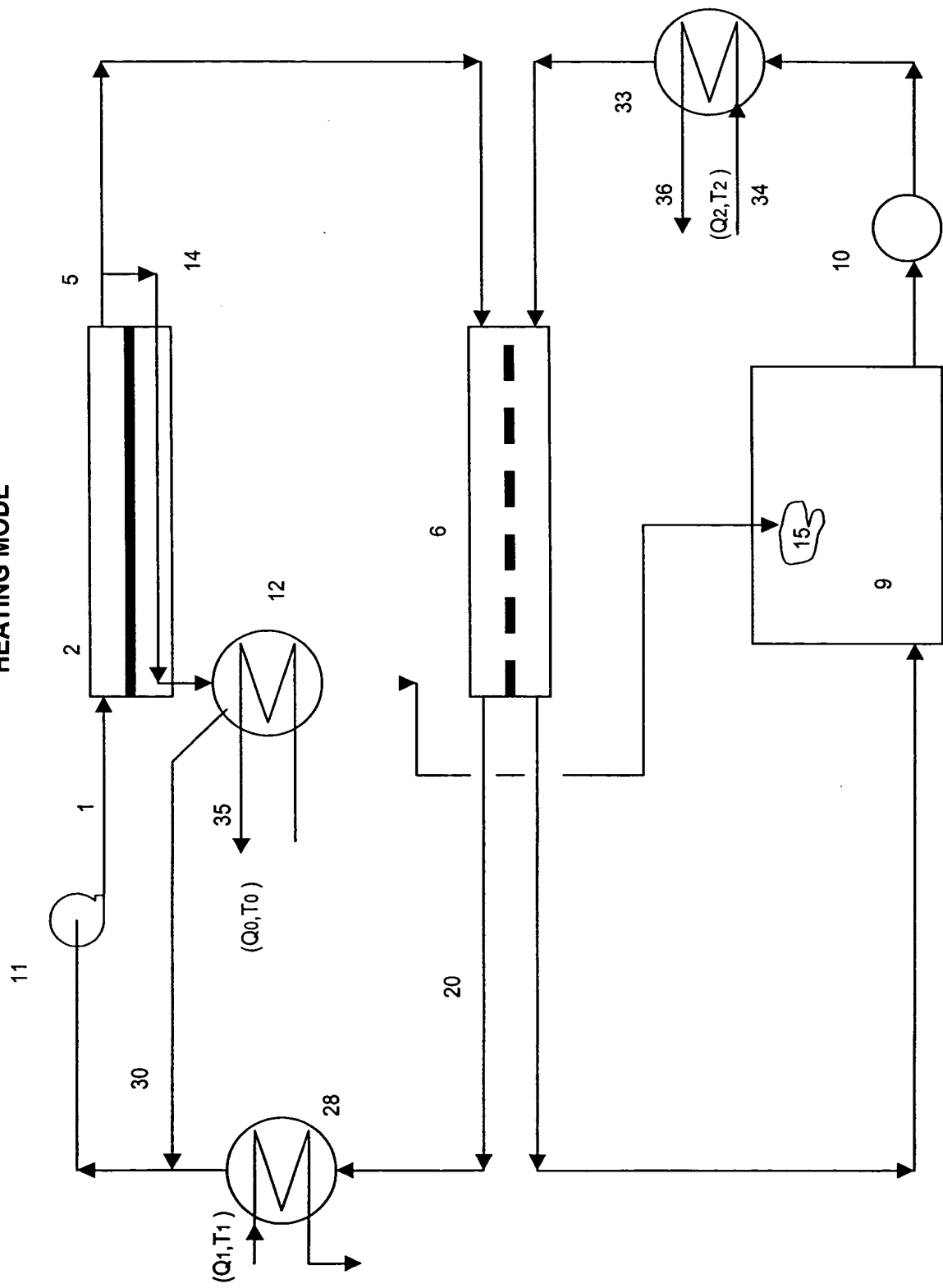


FIG. 14. MEMBRANE HEAT PUMP
HEATING MODE

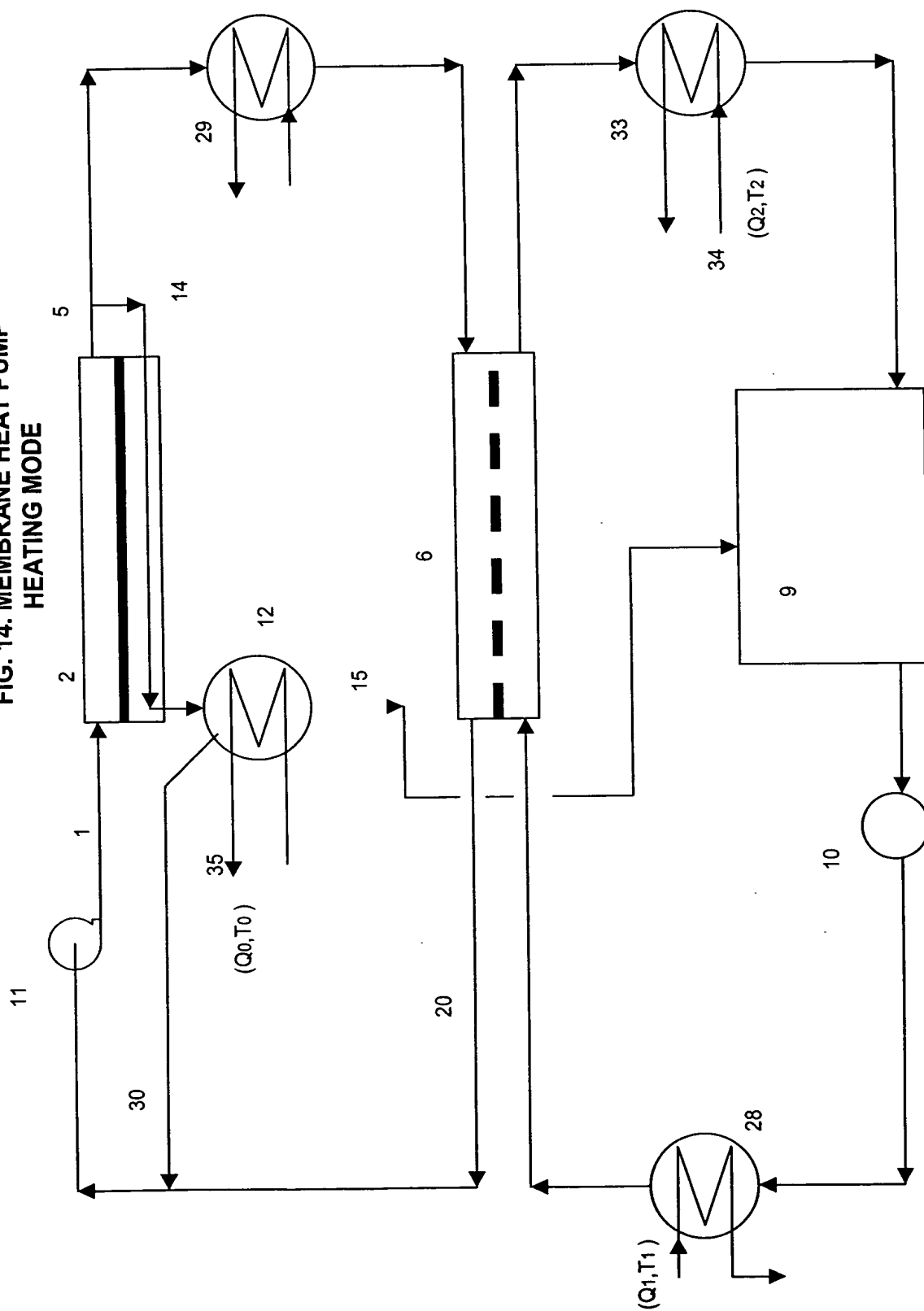


FIG. 15. MEMBRANE HEAT PUMP
RECOVERING HEAT FROM A COOLING TOWER

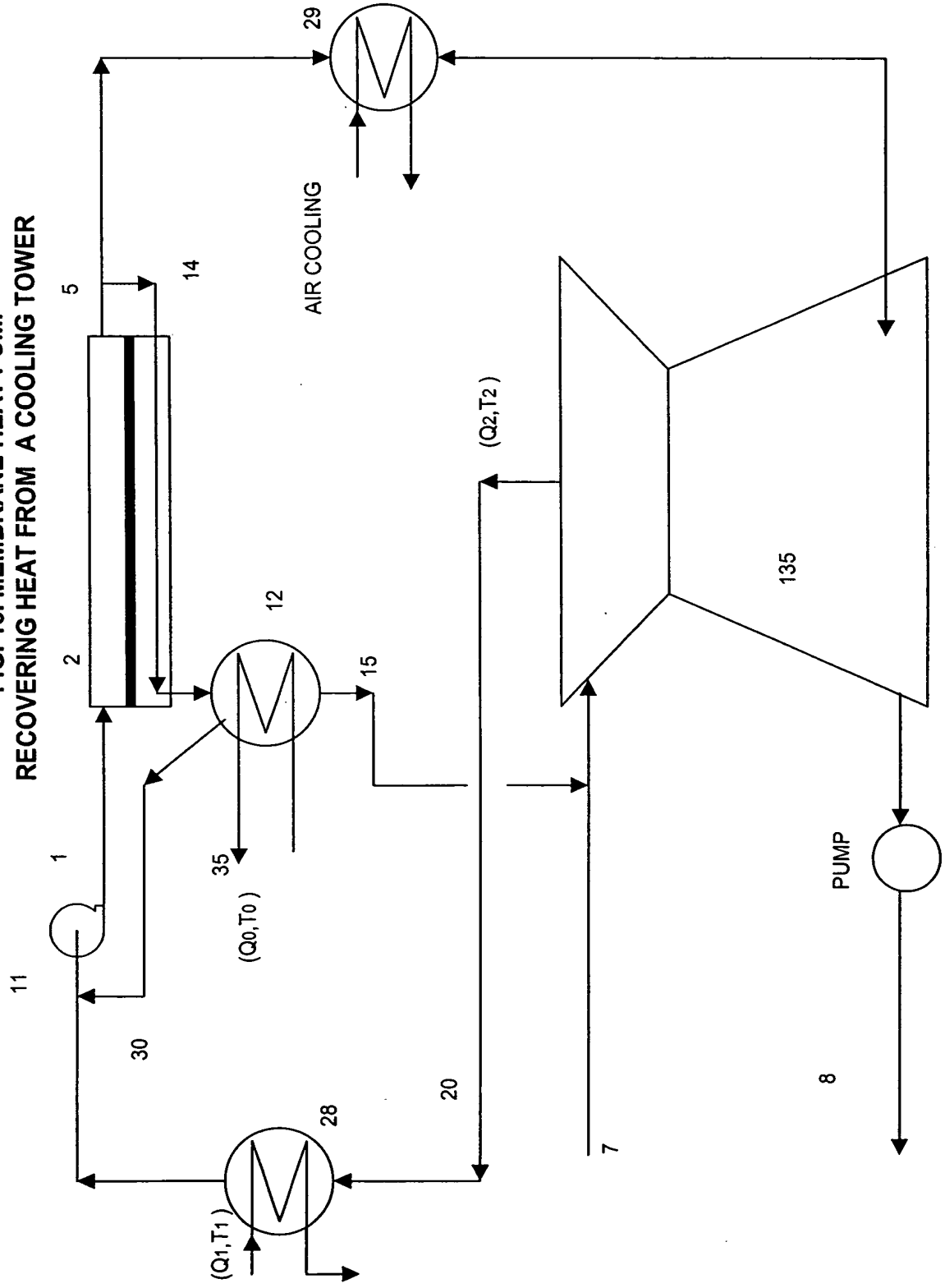


FIG. 16. MEMBRANE HEAT PUMP
RECOVERING HEAT FROM A COOLING TOWER

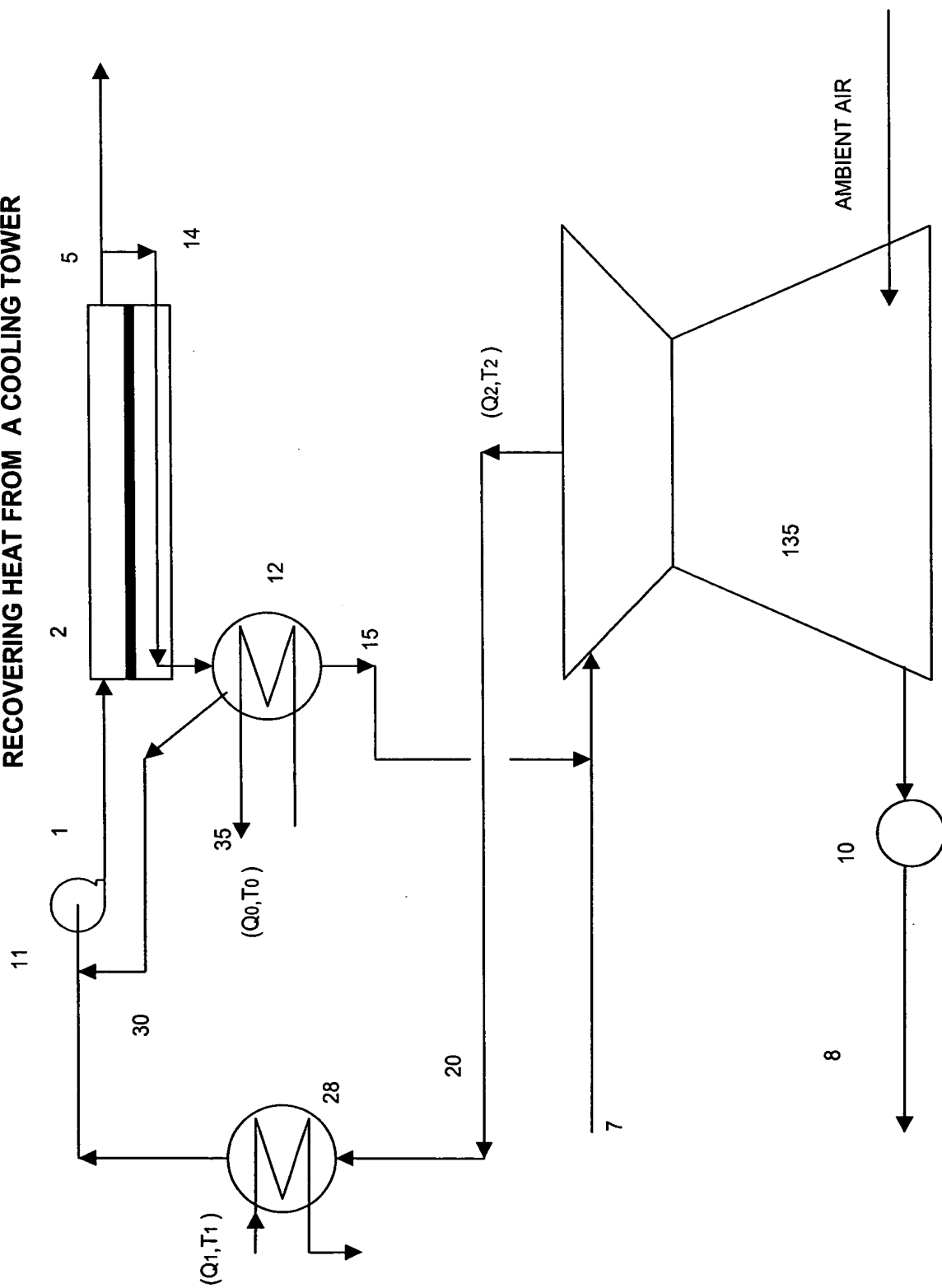


FIG. 17. HEAT PUMP PERFORMANCE
 t_2 HEAT TAKING TEMPERATURE = 40 DEG C

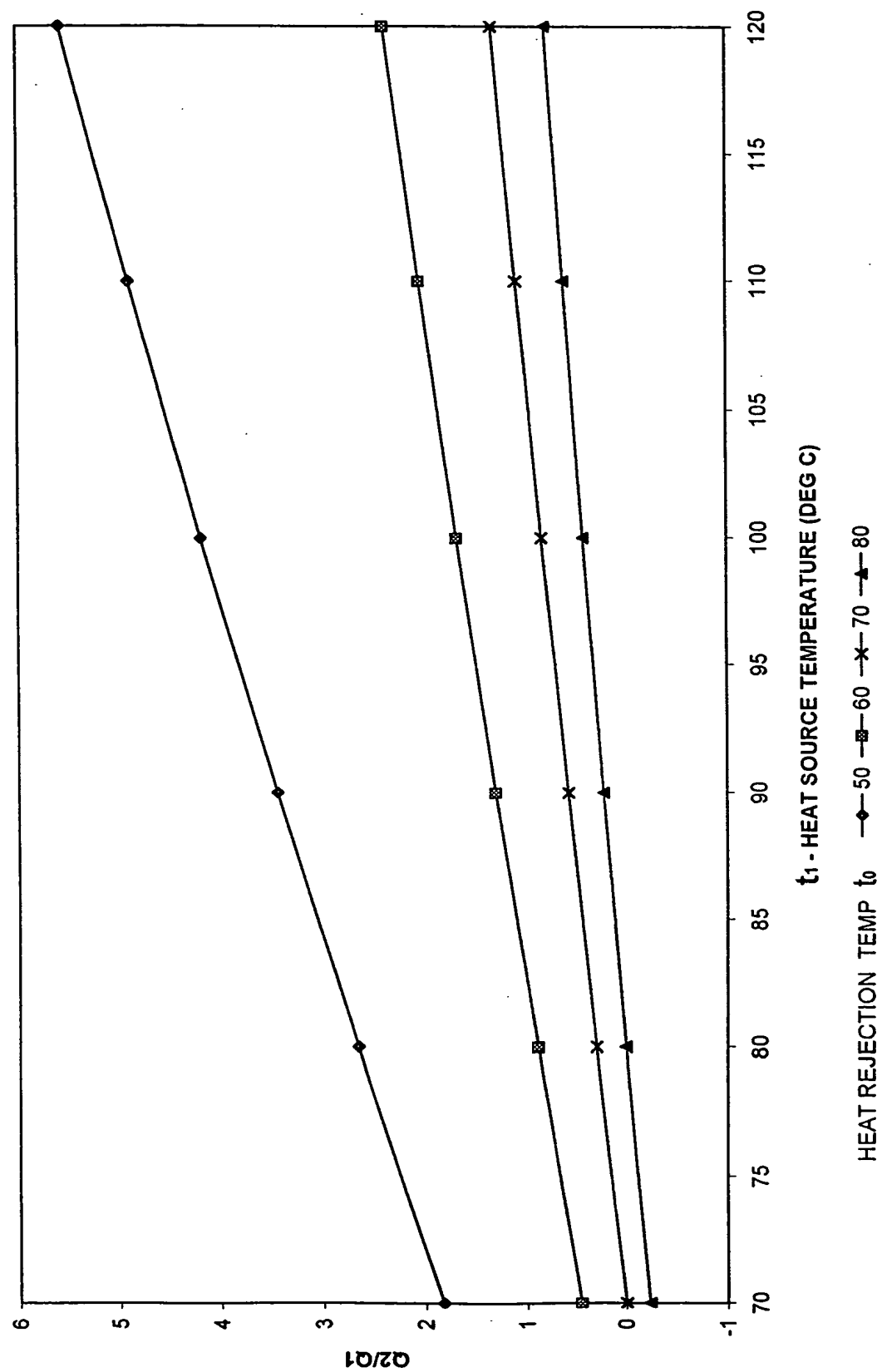


FIG. 18. HEAT PUMP PERFORMANCE
 t_1 HEAT SOURCE TEMPERATURE = 120 DEG C

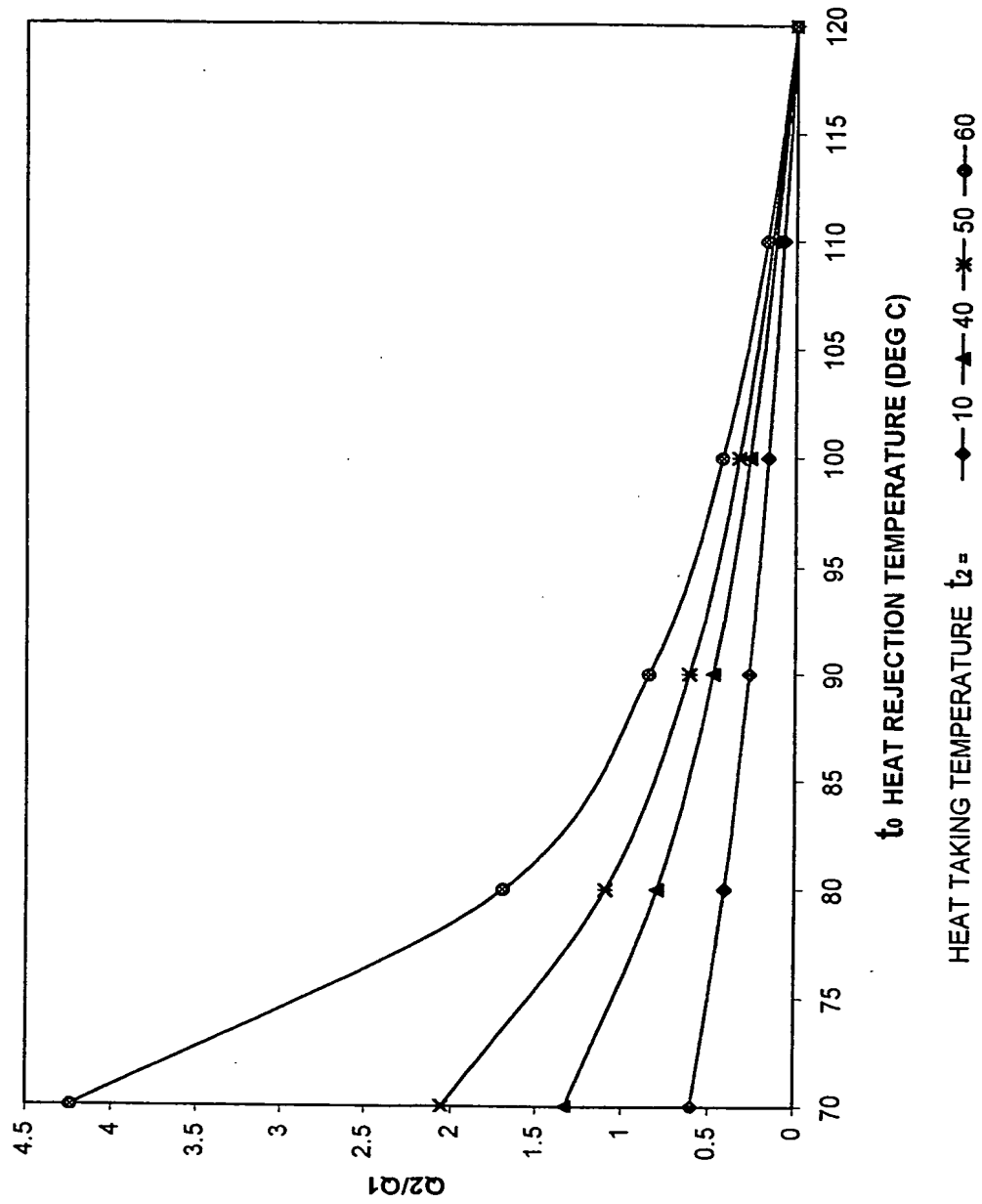


FIG. 19. MEMBRANE HEAT PUMP PROCESS SHOWN ON A PSYCHOMETRIC CHART

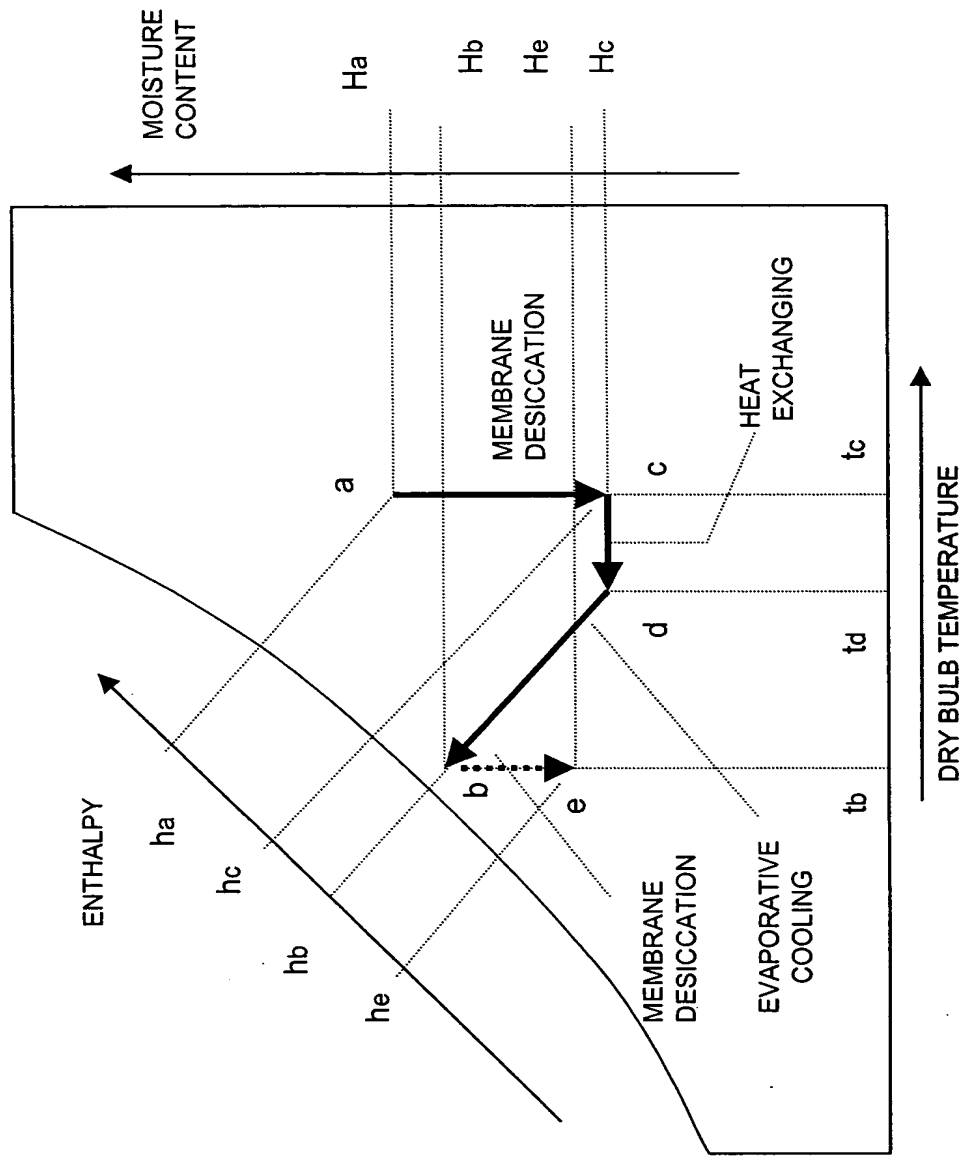


FIG. 20. CLOSED AIR CYCLE
SHOWN ON A PSYCHOMETRIC CHART

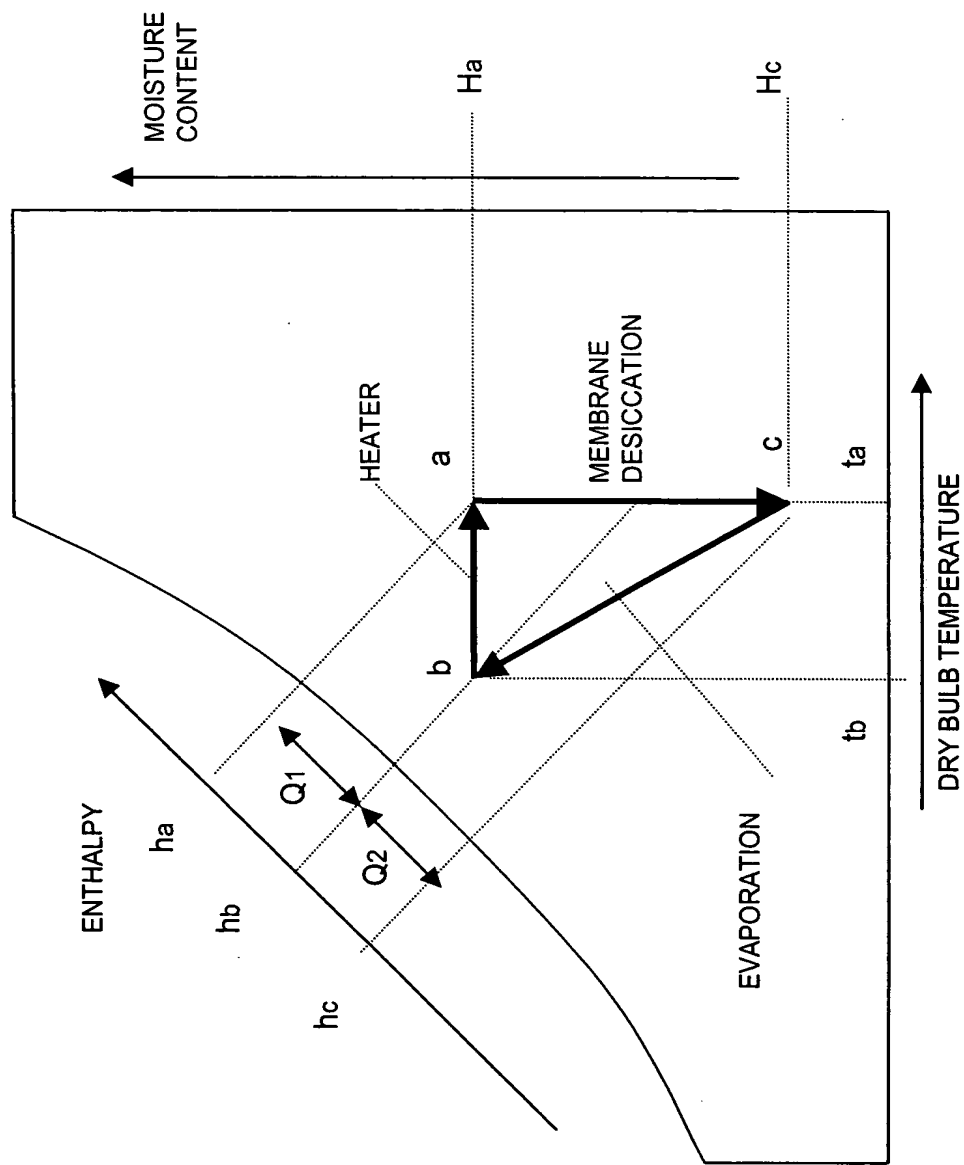


FIG. 22. OPEN CYCLE MEMBRANE HEAT PUMP PROCESS FOR WASTE HEAT RECOVERY SHOWN ON A PSYCHOMETRIC CHART

